

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
5 June 2003 (05.06.2003)

PCT

(10) International Publication Number
WO 03/046253 A1

- (51) International Patent Classification?: **C23C 16/34**, 16/30
- (21) International Application Number: PCT/EP02/13869
- (22) International Filing Date:
27 November 2002 (27.11.2002)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
2001-367126 30 November 2001 (30.11.2001) JP
- (71) Applicant (*for all designated States except US*): **L'AIR LIQUIDE, SOCIETE ANONYME A DIRECTOIRE ET CONSEIL DE SURVEILLANCE POUR L'ETUDE ET L'EXPLOITATION DES PROCEDES GEORGES CLAUDE** [FR/FR]; 75, quai d'Orsay, F-75321 Paris Cedex 07 (FR).
- (72) Inventors; and
- (73) Inventors/Applicants (*for US only*): **DUSSARRAT, Christian** [FR/JP]; Wadai 28, Tsukuba, Ibaraki 300-4247 (JP). **GIRARD, Jean-Marc** [FR/FR]; 12, rue Michel Chasles, F-75012 Paris (FR).
- (74) Agents: **VESIN, Jacques et al.**; L'Air Liquide S.A., 75, quai d'Orsay, F-75321 Paris Cedex 07 (FR).
- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:**
— with international search report
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

WO 03/046253 A1

(54) Title: METHOD FOR DEPOSITING SILICON NITRIDE FILMS AND SILICON OXYNITRIDE FILMS BY CHEMICAL VAPOR DEPOSITION

(57) Abstract: (Problem) To provide a method for the production of silicon nitride and silicon oxynitride films by CVD technology, wherein said method provides acceptable film - deposition rates even at lower temperatures and is not accompanied by the production of large amounts of ammonium chloride. (Solution) Use of a hydrocarbylaminodisilane compound with the formula $(R^0)_3\text{-Si-Si-(R}^0)_3$ (I) (each R^0 is independently selected from the hydrogen atom, chlorine atom, and $-\text{NR}^1(\text{R}^2)$ groups (wherein R^1 and R^2 are each independently selected from the hydrogen atom and C_1 to C_4 hydrocarbyl with the proviso that R^1 and R^2 may not both be the hydrogen atom) and at least one R^0 is the $-\text{NR}^1(\text{R}^2)$ group) as a precursor for silicon nitride and silicon oxynitride.

Methods for depositing silicon nitride films and silicon oxynitride films
by chemical vapor deposition

This invention relates to methods for producing silicon nitride films and silicon oxynitride
5 films by chemical vapor deposition (CVD).

Description of the Prior Art

Silicon nitride films exhibit excellent barrier properties and an excellent oxidation
resistance and for these reasons are used for, for example, etch-stop layers, barrier layers, gate
10 insulation layers, and ONO stacks in the fabrication of microelectronic devices.

The main technologies in use at the present time for the formation of silicon nitride films
are plasma-enhanced CVD (PECVD) and low-pressure CVD (LPCVD).

In PECVD, a silicon source (typically a silane) and a nitrogen source (typically ammonia
but more recently nitrogen) are introduced between a pair of parallel -plate electrodes and high-
15 frequency energy is applied between the two electrodes at low temperatures (about 300°C) and
intermediate pressures (0.1 to 5 Torr) in order to generate a plasma from the silicon source and
nitrogen source. Active silicon species and active nitrogen species in the generated plasma react
with each other to produce a silicon nitride film. The silicon nitride films produced by PECVD
generally do not have a stoichiometric composition and are also hydrogen rich. As a result, these
20 silicon nitride films have a low film density and a high etch rate and are of poor quality.

LPCVD, which does not employ a plasma, is used in order to deposit high-quality silicon
nitride films. LPCVD as it is currently practiced uses low pressures (0.1 to 2 Torr) and high
temperatures (750-900°C) and produces silicon nitride films of a quality superior to that of the
silicon nitride films produced by PECVD. Silicon nitride films have generally been produced by
25 this LPCVD technology by the reaction of dichlorosilane (DCS) and ammonia gas. However, the
existing LPCVD technology requires fairly high temperatures in order to obtain acceptable
deposition (film formation) rates ($\geq 10 \text{ Å/minute}$) for silicon nitride films. For example,
temperatures of 750 to 800°C are typically used for the reaction of DCS and ammonia. In
addition, the reaction of DCS and ammonia produces large amounts of ammonium chloride,
30 which can accumulate in and clog the exhaust plumbing system of the CVD reaction apparatus.

A number of silicon nitride precursors have been introduced for the purpose of obtaining satisfactory silicon nitride film deposition rates at low temperatures. Hexachlorodisilane (HCDS) is one example of such precursors. HCDS produces SiCl_2 at relatively low temperatures by the reaction $\text{Si}_2\text{Cl}_6 \rightarrow \text{SiCl}_2 + \text{SiCl}_4$ and this SiCl_2 reacts well with ammonia. The use of HCDS can provide silicon nitride film deposition at film formation rates of approximately 10 Å/minute at 600°C.

Another example of these precursors is the bis(tert-butylamino)silane (BTBAS) described in United States Patent No. 5,874,368. Use of BTBAS can also provide silicon nitride film deposition at lower temperatures than for the use of DCS. As in the case of HCDS, BTBAS enables the deposition of silicon nitride films at a film formation rate of approximately 10 Å/minute at 600°C.

While both HCDS and BTBAS can achieve film formation rates of approximately 10 Å/minute at 600°C, this performance level also means that commercially acceptable film formation rates will not be obtained at lower temperatures $\leq 550^\circ\text{C}$, or in specific terms that a film formation rate of at least 10 Å/minute will not be obtained at lower temperatures $\leq 550^\circ\text{C}$. These two precursors are also associated with the disadvantages described below.

HCDS, being a completely chlorinated disilane, has a high chlorine content, and the Si-Cl bond is also very strong. As a consequence, the chlorine content in the resulting silicon nitride film will increase as the reaction temperature declines, and it has been found that the chlorine content reaches as high as about 2 atom% at a 600°C reaction temperature. In addition, HCDS also leads to the production of large amounts of ammonium chloride just as in the case of DCS.

BTBAS has an activation energy of 56 kcal/mole, with the result that its silicon nitride film formation rate declines drastically when the reaction temperature is reduced. It is estimated that its film formation rate drops to a quite small 3 Å/minute at a reaction temperature of 550°C.

The same problems appear when the aforementioned prior art precursors are used to produce silicon oxynitride films, which have the same physical properties and applications as silicon nitride films.

Problems to Be Solved by the Invention

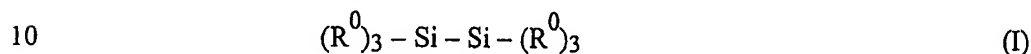
The issue addressed by this invention, therefore, is to provide a method for the production of silicon nitride and silicon oxynitride films by CVD technology, wherein said method provides acceptable film formation rates even at lower temperatures and is not accompanied by the production of large amounts of ammonium chloride.

5

Means Solving the Problems

The first aspect of this invention provides a method for producing silicon nitride films by chemical vapor deposition, said method being characterized by

introducing a hydrocarbylaminodisilane compound with the general formula



wherein

each R^0 is independently selected from the hydrogen atom, chlorine atom, and $-NR^1(R^2)$ groups (wherein R^1 and R^2 are each independently selected from the hydrogen atom and C_1 to C_4 hydrocarbyl with the proviso that R^1 and R^2 may not both be the hydrogen atom) and at least one R^0 is the $-NR^1(R^2)$ group

15

and a nitrogen-containing gas selected from the group consisting of ammonia, hydrazine, alkylhydrazine compounds, and hydrogen azide into a reaction chamber loaded with at least 1 substrate and

forming a silicon nitride film on the substrate by reacting the hydrocarbylaminodisilane compound and nitrogen-containing gas at a reaction temperature.

20

The second aspect of this invention provides a method for producing silicon oxynitride films by chemical vapor deposition, characterized by

introducing a hydrocarbylaminodisilane compound with formula (I), a nitrogen-containing gas selected from the group consisting of ammonia, hydrazine, and hydrogen azide, and an oxygen-containing gas selected from the group consisting of NO , N_2O , NO_2 , O_2 , O_3 , H_2O , and H_2O_2 into a reaction chamber loaded with at least 1 substrate and

25

forming a silicon oxynitride film on the substrate by reacting the hydrocarbylaminodisilane compound, nitrogen-containing gas, and oxygen-containing gas at a reaction temperature.

5 Embodiments of the Invention

This invention will be explained in greater detail in the following.

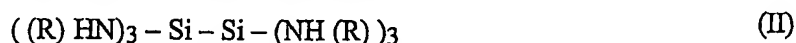
This invention uses special compounds as precursors for silicon nitride and silicon oxynitride (collectively referred to below as silicon (oxy)nitride) in the formation of silicon nitride films and silicon oxynitride films (collectively referred to below as silicon (oxy)nitride films) on
10 substrates by thermal CVD technology.

The silicon (oxy)nitride precursors used in this invention are hydrocarbylaminodisilane compounds with formula (I).



Each R^0 in (I) is independently selected from the hydrogen atom, chlorine atom, and the –
15 $NR^1(R^2)$ group and at least one group R^0 must be the $-NR^1(R^2)$ group. R^1 and R^2 in the –
 $NR^1(R^2)$ group are each independently selected from the hydrogen atom and C_1 to C_4
hydrocarbyl with the proviso that R^1 and R^2 may not both be the hydrogen atom. The C_1 to C_4
hydrocarbyl includes vinyl and C_1 to C_4 alkyl such as methyl, ethyl, propyl, isopropyl, butyl, and
tert-butyl.

20 Compounds in which each R^0 is $-NR^1(R^2)$, R^1 is the hydrogen atom, and R^2 is C_1 to C_4
hydrocarbyl, that is, hexakis(monohydrocarbylamino)disilanes with formula (II)



(each R independently represents C_1 to C_4 hydrocarbyl) are novel compounds and are preferred
compounds within the scope of this invention.

Hexakis(monohydrocarbylamino)disilanes with formula (II) can be synthesized by
25 reacting hexachlorodisilane ($Cl_3-Si-Si-Cl_3$) in organic solvent with at least 6-fold moles of the
monohydrocarbylamine RNH_2 ($R = C_1$ to C_4 hydrocarbyl). The monohydrocarbylamine for

reaction with hexachlorodisilane includes, inter alia, methylamine, ethylamine, propylamine, isopropylamine, tert-butylamine, and vinylamine. The monohydrocarbylamine used can take the form of a single monohydrocarbylamine or a mixture of monohydrocarbylamines. However, the use of a single monohydrocarbylamine is preferred viewed from the perspective of ease of production, and the use of ethylamine is even more preferred.

As specified above, the hexachlorodisilane and monohydrocarbylamine are reacted with each other using at least 6 moles of the latter per 1 mole of the former. However, the use of a large excess of the monohydrocarbylamine over hexachlorodisilane is preferred for the purpose of inhibiting the production of N-hydrocarbyldisilazane. In specific terms, the use of a hexachlorodisilane : monohydrocarbylamine molar ratio of 1 : 12 to 1 : 36 is preferred. Use of at least 12 moles monohydrocarbylamine per 1 mole hexachlorodisilane also enables trapping, as the monohydrocarbylamine hydrochloride (solid), of the hydrogen chloride (6 moles) that is produced as a by-product in the reaction. This monohydrocarbylamine hydrochloride can be easily removed from the reaction mixture post-reaction by filtration.

Organic solvent is used as the reaction solvent for reaction of the hexachlorodisilane and monohydrocarbylamine. This organic solvent encompasses tetrahydrofuran and straight-chain and cyclic hydrocarbons, for example, pentane, hexane, and octane. Pentane is the preferred solvent.

The reaction between hexachlorodisilane and monohydrocarbylamine is preferably run at a temperature from -30°C to $+50^{\circ}\text{C}$. In general, this reaction will be run by first bringing the reaction solvent to a temperature in the preferred range of -30°C to $+50^{\circ}\text{C}$, introducing the monohydrocarbylamine into the reaction solvent and dissolving it therein, and then gradually adding the hexachlorodisilane, for example, by dropwise addition. The hexachlorodisilane can be dropped in either neat or dissolved in the same solvent as the reaction solvent. The reaction is subsequently run for 2 to 24 hours while stirring the reaction solvent and holding at the aforementioned temperature. After this period of stirring, the reaction solvent is heated to room temperature (approximately 20°C to 50°C) and stirring is preferably continued for at least another 10 hours. The hydrocarbylammonium chloride, a solid by-product, is then filtered off and the solvent and residual amine are distilled off in vacuo. The resulting hexakis(monohydrocarbylamino)disilane can be subjected to additional purification by fractional distillation.

The hexakis(monohydrocarbylamino)disilanes (II) are liquids at ambient temperatures (approximately 20°C to 50°C), do not contain chlorine, and are highly reactive and in particular support excellent silicon (oxy)nitride film formation rates at low temperatures ($\leq 600^\circ\text{C}$). Their high reactivity is caused by the bonding of the monohydrocarbylamino group to the silicon and
5 by the weak Si – Si direct bond. Hexakis(monoethylamino)disilane is a particularly preferred hexakis(monohydrocarbylamino)disilane (II).

In order to form silicon nitride using the inventive hydrocarbylaminodisilane compounds (I), the hydrocarbylaminodisilane compound (I) and nitrogen-containing gas are admitted into a reaction chamber loaded with at least 1 substrate (typically a semiconductor substrate such as a
10 silicon substrate) and silicon nitride is deposited on the semiconductor substrate by reacting the hydrocarbylaminodisilane compound and nitrogen-containing gas at the reaction temperature. The nitrogen-containing gas can be selected from the group consisting of ammonia, hydrazine, alkylhydrazine compounds, and hydrogen azide.

The molar ratio between the hydrocarbylaminodisilane compound and nitrogen-
15 containing gas admitted into the reaction chamber during silicon nitride production is preferably 1 : 0 to 1 : 50. The total pressure within the reaction chamber is preferably maintained at from 0.1 to 10 Torr. The reaction temperature is preferably from -300°C to 650°C .

In order to form silicon oxynitride using the inventive hydrocarbylaminodisilane compounds (I), the hydrocarbylaminodisilane compound (I), nitrogen-containing gas, and
20 oxygen-containing gas are admitted into a reaction chamber loaded with at least one substrate (typically a semiconductor substrate such as a silicon substrate) and a silicon oxynitride film is deposited on the substrate by reacting the hydrocarbylaminodisilane compound, nitrogen-containing gas, and oxygen-containing gas at the reaction temperature. As with silicon nitride film deposition, the nitrogen-containing gas can be selected from the group consisting of
25 ammonia, hydrazine, and hydrogen azide. The oxygen-containing gas can be selected from the group consisting of NO, N₂O, NO₂, O₂, O₃, H₂O, and H₂O₂.

When the oxygen-containing gas also contains nitrogen (NO, N₂O, and/or NO₂), the nitrogen-containing gas need not be used and the ratio between the hydrocarbylaminodisilane compound and the nitrogen-containing gas admitted into the reaction chamber during silicon
30 oxynitride production is preferably 1 : 0 to 1 : 50. When the oxygen-containing gas does not

contain nitrogen (O_2 , O_3 , H_2O , and/or H_2O_2), the molar ratio between the hydrocarbylaminodisilane compound and the nitrogen-containing gas is preferably 10 : 1 to 1 : 50. In either case the molar ratio between the hydrocarbylaminodisilane compound and oxygen-containing gas is preferably 50 : 1 to 1 : 10. The overall pressure within the reaction chamber is preferably maintained in the range from 0.1 to 10 Torr, and the reaction temperature is preferably -300°C to 750°C.

The hydrocarbylaminodisilane compound (I) can be vaporized using a bubbler or a vaporizer during silicon (oxy)nitride production according to this invention. The bubbler can comprise a sealed container filled with liquid hydrocarbylaminodisilane compound (I), an injection conduit that injects carrier gas into the hydrocarbylaminodisilane compound in the sealed container, and a feed conduit that removes hydrocarbylaminodisilane compound — vaporized and entrained into the carrier gas injected from the injection conduit into the hydrocarbylaminodisilane compound — from the sealed container and feeds this vaporized hydrocarbylaminodisilane compound into the reaction chamber. At its downstream end this feed conduit communicates with the CVD reaction chamber. The temperature and pressure within the sealed container must be maintained at constant or specified values.

A Direct Liquid Injection System (DLI-25) from the MKS Company or a VU-410A vaporizer from the Lintec Company, for example, can be used as the vaporizer. The hydrocarbylaminodisilane compound is vaporized using the vaporizer and fed to the reaction chamber.

Figure 1 contains a block diagram that illustrates one example of a CVD reaction apparatus well suited for execution of the inventive method for producing silicon (oxy)nitride films.

The CVD reaction apparatus 10 illustrated in Figure 1 is provided with a CVD reaction chamber 11, a supply source 12 for the hydrocarbylaminodisilane compound (HCAD) according to this invention, a nitrogen-containing gas supply source 13, and a supply source 14 of dilution gas, such as an inert gas, that is introduced as necessary. The CVD reaction apparatus 10 is also provided with an oxygen-containing gas supply source 15 when silicon oxynitride is to be produced. The reaction chamber 11 is surrounded by a heating means 111 for the purpose of heating to the specified CVD reaction temperature (batch processing). A susceptor is heated in the case of single wafer processing.

In the case of the CVD reaction apparatus 10 illustrated in Figure 1, the HCAD is introduced into the reaction chamber 11 in the gas phase due to the action of a bubbler. The HCAD supply source 12 is provided with a sealed container 121 that is loaded with liquid HCAD. An injection conduit 122 is inserted into the sealed container 121 in order to inject
5 carrier gas into the HCAD loaded in the sealed container 121; the carrier gas is injected from the supply source 16 for the carrier gas, e.g., nitrogen, across the valve V1 and mass flow controller MFC1. After its injection into the HCAD, the HCAD-entraining carrier gas passes through the pressure-control valve PV and into the line L1 and is introduced into the reaction chamber 11. A pressure sensor PG1 is connected to the line L1. Although not shown in the figure, at least 1
10 substrate (typically a semiconductor substrate such as a silicon substrate) is loaded in the reaction chamber 11. From 1 to 250 substrates (chuck- or wafer boat-loaded) can be present.

Nitrogen-containing gas, e.g., ammonia, is introduced from the nitrogen-containing gas supply source 13 across the valve V2 and the mass flow controller MFC2 and into the reaction chamber 11 through the line L2.

15 Dilution gas, which is introduced as necessary, can be introduced from the dilution gas supply source 14 across the valve V3 and the mass flow controller MFC3 and into the reaction chamber 11 through the line L3 and the line L2.

Oxygen-containing gas, which is introduced during production of silicon oxynitride films, can be introduced from the oxygen-containing gas supply source 15 across the valve V4 and the
20 mass flow controller MFC4 and into the reaction chamber 11 through the line L4 and the line L2.

The outlet from the reaction chamber 11 is connected by the line L5 to a waste gas treatment apparatus 17. This waste gas treatment apparatus 17 functions to remove, for example, by-products and unreacted material, and to exhaust the gas after abatement from the system. A
25 pressure sensor PG2, a butterfly valve BV, and a pump PM are connected in the line L5. The various gases are introduced into the reaction chamber 11, the pressure within the reaction chamber 11 is monitored by the pressure sensor PG2, and the pressure is brought to its prescribed value by the opening and closing of the butterfly valve BV by the operation of the pump PM.

During operation, the container 121 is heated to, for example, 50°C to 80°C, and the HCAD feed system, which comprises the line L1, is preferably heated to a temperature higher than the bubbler in order to prevent dew formation by the HCAD.

Figure 2 contains a CVD reaction apparatus that has the same structure as the CVD reaction apparatus 10 illustrated in Figure 1, with the exception that the CVD reaction apparatus in Figure 2 contains a different HCAD feed system. Those elements that are the same in both figures have been assigned the same reference symbol and will not be considered again in detail.

The CVD reaction apparatus 20 illustrated in Figure 2 is provided with a vaporizer 21. Carrier gas from the carrier gas source 16 passes across the valve V1 and through the line L21 and is introduced into the gas-phase region for the HCAD filled in liquid form in the sealed container 22. The pressure exerted by the carrier gas functions to move the liquid HCAD across the valve V22 and the mass flow controller MFC21, through the line L22, and into the vaporizer 21. Carrier gas from the carrier gas source 16 also passes through the line L22, which branches from the line L21, and is introduced into the vaporizer 21. The carrier gas and liquid HCAD introduced into the vaporizer 21 are heated in the vaporizer 21 to, for example, 60°C to 200°C, and the HCAD is vaporized and is transported with the carrier gas through the line L23 and is introduced into the reaction chamber 11. The line L23 is preferably heated to 50°C to -250°C in order to prevent reliquefaction or dew formation by the HEAD.

Examples

This invention is described in greater detail in the following through working examples, but the invention is not limited to these examples.

25

Synthesis Example 1

Synthesis of hexakis(monoethylamino)disilane (HEAD)

Pentane was used as the reaction solvent and was cooled to 0°C for the reaction. An ethylamine solution was prepared by adding ethylamine (70 g, 1.55 mol) cooled to 0°C to the cold pentane. Hexachlorodisilane (26.9 g, 0.1 mol) was gradually added to this ethylamine solution. The resulting reaction solution was thereafter stirred for 2 hours at 0°C and then for an

30

additional 15 hours at room temperature (20°C). The ethylammonium -chloride by-product was filtered off and the pentane and ethylamine were distilled out in vacuo. 22.4 g HEAD was obtained (yield = 70%).

Results of analysis

5 $^1\text{H-NMR}$ (C_6D_6 , 500 MHz): $\delta = 0.61$ ppm (broad, $-\text{NH}$), $\delta = 1.1$ ppm (triplet, $-\text{CH}_3$), $\delta = 2.95$ (pentet, $-\text{CH}_2$)

$^{13}\text{C-NMR}$ (C_6D_6 , 125 MHz): 20.7 ppm and 36.1 ppm ($-\text{CH}_2-\text{CH}_3$)

A signal assignable to the SiH bond was not observed in these NMR analyses.

Figure 3 reports the analytical results (spectrum) from QMS ($m/e < 250$) (Et = ethyl in
10 Figure 3). While the Si-Si bond was present in a number of fragments, for the sake of simplicity assignments are given only for main peaks.

The chlorine content of the synthesized HEAD product, as measured by ion chromatography, was no greater than trace levels. The melting point of the HEAD product was estimated -about 10 C.

15

Example 1

-Deposition of silicon nitride film

A silicon nitride film was deposited in this example on a silicon semiconductor substrate
20 using a CVD reaction apparatus that had the same structure as the CVD reaction apparatus in Figure 2. The HEAD synthesized in Synthesis Example 1 was used as the HCAD; ammonia was used as the nitrogen-containing gas; and nitrogen was used as the carrier gas. The conditions listed below were used to produce the silicon nitride film. The line L23 was heated to 110°C during -deposition.

25 HEAD gas flow rate: 5 sccm

ammonia gas flow rate: 50 sccm

carrier gas (nitrogen) flow rate: 60 sccm

pressure within the reaction chamber: 0.5 Torr

reaction chamber temperature: 550°C

30 vaporizer temperature: 110°C

A silicon nitride film with a thickness of 900 Å was obtained in about 45 minutes as a result (silicon nitride film deposition rate = 20 Å/minute). This silicon nitride film had a composition of $\text{Si}_{1.5}\text{N}_1$ according to analysis by Auger electron spectroscopy.

Using conditions that were otherwise the same as those listed above, silicon nitride films were fabricated using reaction chamber temperatures of 500°C and 525°C. Silicon nitride films were obtained at deposition rates of 10 Å/minute and 15 Å/minute, respectively.

Example 2

-Deposition of silicon oxynitride film

10

A silicon oxynitride film was deposited in this example on a silicon semiconductor substrate using a CVD reaction apparatus that had the same structure as the CVD reaction apparatus in Figure 2. The HEAD synthesized in Synthesis Example 1 was used as the HCAD; ammonia was used as the nitrogen-containing gas; oxygen was used as the oxygen-containing gas; and nitrogen was used as the carrier gas. The conditions listed below were used to produce the silicon oxynitride film. The line L23 was heated to 110°C during production.

15

HEAD gas flow rate: 2 sccm

ammonia gas flow rate: 50 sccm

oxygen flow rate: 1 sccm

20

carrier gas (nitrogen) flow rate: 60 sccm

pressure within the reaction chamber: 0.5 Torr

reaction chamber temperature: 550°C

vaporizer temperature: 110°C

A silicon oxynitride film with a thickness of approximately 2,000 Å was obtained in about 100 minutes as a result (silicon oxynitride film deposition rate = 20 Å/minute). This silicon oxynitride film had a composition of $\text{SiN}_{0.42}\text{O}_{0.35}$ according to analysis by Auger electron spectroscopy.

25

Advantageous Effects of the Invention

30

As has been described in the preceding, this invention enables the - deposition of silicon nitride and silicon oxynitride films by CVD technology at satisfactory film formation rates even at low temperatures and does so without being accompanied by the -deposition of large amounts of ammonium chloride.

5

Example 3

Production of silicon nitride film

A silicon nitride film was deposited in this example on a silicon semiconductor substrate using a CVD reaction apparatus that had the same structure as the CVD reaction apparatus in Figure 2. The HEAD synthesized in Synthesis Example 1 was used as the HCAD; no nitrogen-containing gas was introduced, and nitrogen was used as the carrier gas. The conditions listed below were used to produce the silicon nitride film. The line L23 was heated to 110°C during production.

HEAD gas flow rate: 1.5 sccm
carrier gas (nitrogen) flow rate: 15 sccm
pressure within the reaction chamber: 1 Torr
reaction chamber temperature: 450°C
vaporizer temperature: 110°C

A silicon nitride film with a thickness of about 1250 Å was obtained in about 150 minutes as a result (silicon nitride film deposition rate = about 8 Å/minute). According to Auger electron spectroscopy the Si to N ratio is about 1.5

Brief Description of the Drawings

Figure 1 contains a block diagram that illustrates an example of a CVD reaction apparatus that can be used to carry out the invention.

Figure 2 contains a block diagram that illustrates another example of a CVD reaction apparatus that can be used to carry out the invention.

Figure 3 contains the mass spectrum of the hexakis(monoethylamino)disilane synthesized in Synthesis Example 1.

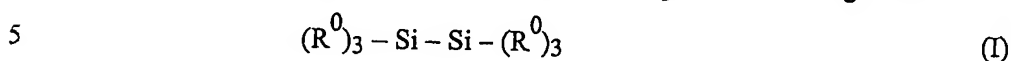
30

Reference symbols

10, 20	.....	CVD reaction apparatus
11	.....	CVD reaction chamber
12	.....	hydrocarbylaminodisilane (HCAD) supply source
5	13	..... nitrogen-containing gas supply source
	14	..... dilution gas supply source
	15	..... oxygen-containing gas supply source
	16	..... carrier gas supply source
	17	..... waste gas treatment apparatus
10	21	..... vaporizer
	22	..... sealed container
	111	..... heating means
	121	..... sealed container
	122	..... carrier gas injection conduit
15	L1-L5, L21-L23	..... line
	V1-V4, V21-V22	..... valve
	PG1-PG2	..... pressure sensor
	MFC1-MFC4, MFC21-MFC22	..... mass flow controller
	BV	..... butterfly valve
20	PM	..... pump

Claims

1. Method for producing silicon nitride films by chemical vapor deposition, characterized by introducing a hydrocarbylaminodisilane compound with the general formula



wherein

each R^0 is independently selected from the hydrogen atom, chlorine atom, and $-NR^1(R^2)$ groups (wherein R^1 and R^2 are each independently selected from the hydrogen atom and C_1 to C_4 hydrocarbyl with the proviso that R^1 and R^2 may not both be the hydrogen atom) and at least one R^0 is the $-NR^1(R^2)$ group

and a nitrogen-containing gas selected from the group consisting of ammonia, hydrazine, alkylhydrazine compounds, and hydrogen azide into a reaction chamber loaded with at least 1 substrate and forming a silicon nitride film on the substrate by reacting the hydrocarbylaminodisilane compound and nitrogen-containing gas at a reaction temperature.

2. The production method of claim 1, characterized in that the hydrocarbylaminodisilane compound is the compound (I) in which each R^0 is the $-NR^1(R^2)$ group, R^1 is the hydrogen atom, and R^2 is C_1 to C_4 hydrocarbyl.

3. The production method of claim 1 or 2, in which the hydrocarbylaminodisilane compound contains hexakis(ethylamino)disilane.

4. Production method according to any of claims 1 to 3, characterized in that the molar ratio between the aminodisilane compound and nitrogen-containing gas introduced into the reaction chamber is 1 : -0 to 1 : 50; the total pressure within the reaction chamber is 0.1 to 10 Torr; and the reaction temperature is -300°C to 650°C.

5. Production method according to any of claims 1 to 4, characterized in that the hydrocarbylaminodisilane compound is entrained as a gas in the carrier gas by injecting the carrier gas into the liquid form hydrocarbylaminodisilane compound and is then moved through the feed system and fed to the reaction chamber.

5 6. Production method according to any of claims 1 to 4, characterized in that the hydrocarbylaminodisilane compound is vaporized using a vaporizer and the vaporized hydrocarbylaminodisilane compound is then moved through the feed system and fed to the reaction chamber.

7. The production method of claim 6, characterized in that the vaporizer is heated to a
10 temperature of 60°C to 200°C.

8. Production method according to any of claims 5 to 7, characterized in that the feed system is maintained at a temperature of 25°C to -250°C.

9. Production method according to any of claims 1 to 8, wherein the reaction chamber is loaded with from 1 to 250 semiconductor substrates mounted in one chuck or wafer boat.

15 10. Method for producing silicon oxynitride films by chemical vapor deposition, characterized by

introducing a hydrocarbylaminodisilane compound with the general formula



wherein

20 each R^0 is independently selected from the hydrogen atom, chlorine atom, and $-NR^1(R^2)$ groups (wherein R^1 and R^2 are each independently selected from the hydrogen atom and C_1 to C_4 hydrocarbyl with the proviso that R^1 and R^2 may not both be the hydrogen atom) and at least one R^0 is the $-NR^1(R^2)$ group,

25 a nitrogen-containing gas selected from the group consisting of ammonia, hydrazine, alkylhydrazine compounds, and hydrogen azide, and an oxygen-containing gas selected from the group consisting of NO, N_2O , NO_2 , O_2 , O_3 , H_2O , and H_2O_2 into a reaction chamber loaded with at least 1 substrate and

forming a silicon oxynitride film on the substrate by reacting the hydrocarbylaminodisilane compound, nitrogen-containing gas, and oxygen-containing gas at a reaction temperature.

11. The production method of claim 10, characterized in that the hydrocarbylaminodisilane
5 compound is the compound (I) in which each R^0 is the $-NR^1(R^2)$ group, R^1 is the hydrogen atom, and R^2 is C_1 to C_4 hydrocarbyl.

12. The production method of claim 10 or 11, in which the hydrocarbylaminodisilane compound contains hexakis(ethylamino)disilane.

13. Production method according to any of claims 11 to 13, characterized in that the molar
10 ratio between the hydrocarbylaminodisilane compound and nitrogen-containing gas introduced into the reaction chamber is 1 : 0 to 1 : 50; the molar ratio between the hydrocarbylaminodisilane compound and the oxygen-containing gas is 50 : 1 to 1 : 10; the total pressure within the reaction chamber is 0.1 to 10 Torr; and the reaction temperature is -300°C to 750°C .

14. Production method according to any of claims 10 to 13, characterized in that the
15 hydrocarbylaminodisilane compound is entrained as a gas in the carrier gas by injecting the carrier gas into the liquid form hydrocarbylaminodisilane compound and is then moved through the feed system and fed to the reaction chamber.

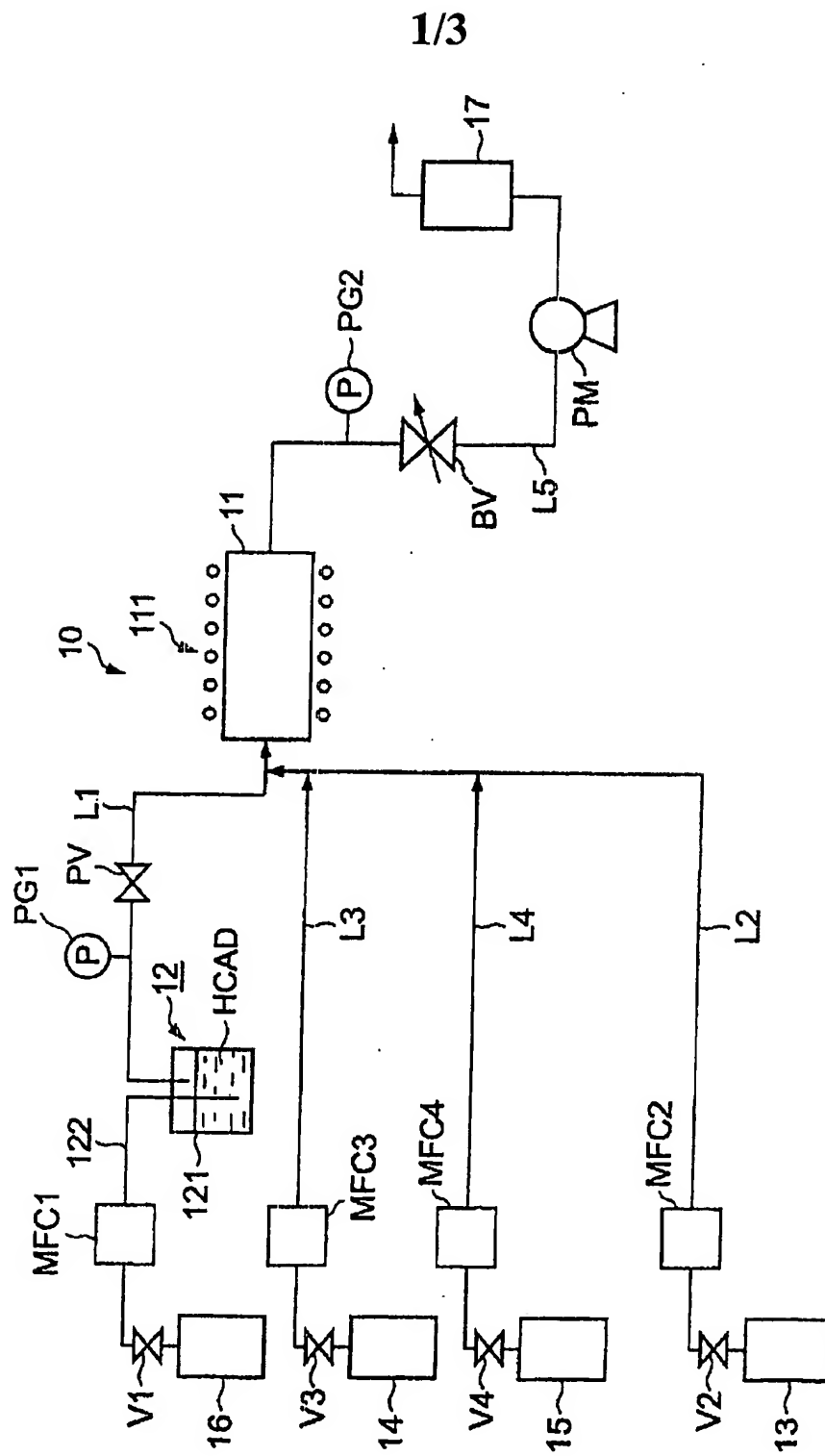
15. Production method according to any of claims 10 to 13, characterized in that the hydrocarbylaminodisilane compound is vaporized using a vaporizer and the vaporized
20 hydrocarbylaminodisilane compound is then moved through the feed system and fed to the reaction chamber.

16. The production method of claim 15, characterized in that the vaporizer is heated to a temperature of 60°C to 200°C .

17. Production method according to any of claims 14 to 16, characterized in that the feed
25 system is maintained at a temperature of 25°C to -250°C .

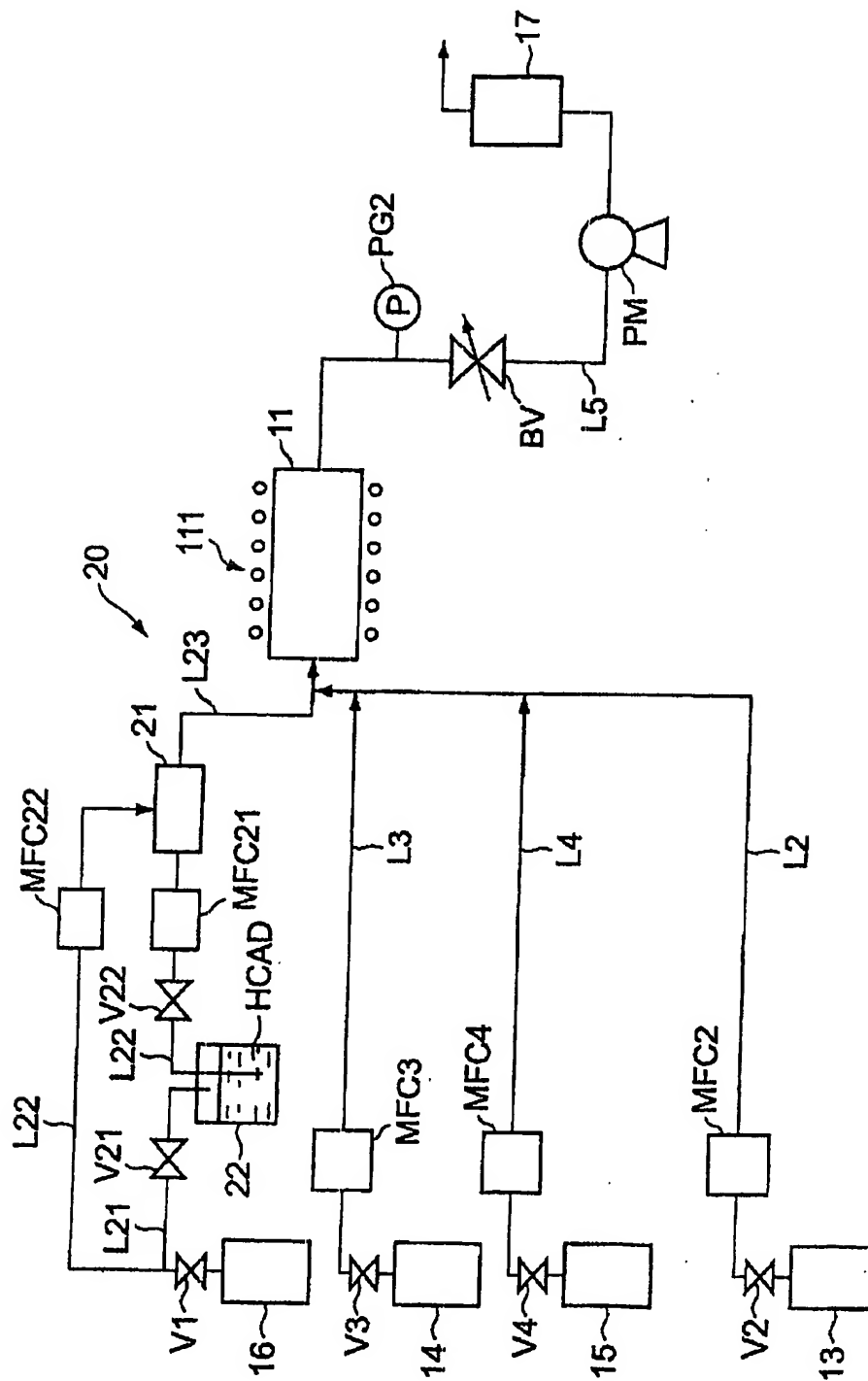
18. Production method according to any of claims 10 to 17, wherein the reaction chamber is loaded with from 1 to 250 semiconductor substrates mounted in one chuck or wafer boat.

Figure 1.



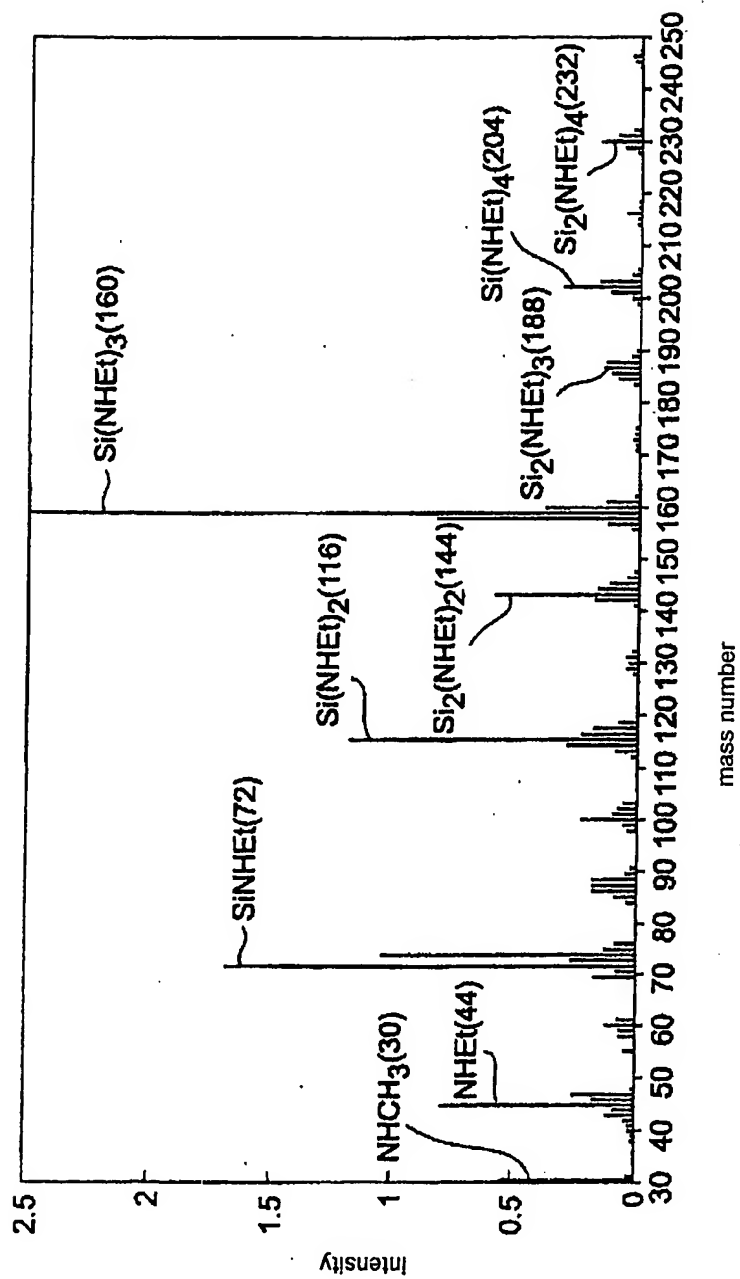
2/3

Figure 2.



3/3

Figure 3.



INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/13869

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C23C16/34 C23C16/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 05, 31 May 1996 (1996-05-31) -& JP 08 022986 A (SONY CORP), 23 January 1996 (1996-01-23) see formula 1 page 6, paragraph 54 ---	1,2, 4-11, 13-18
A	US 5 976 991 A (HOCHBERG ARTHUR KENNETH ET AL) 2 November 1999 (1999-11-02) claims 1-9 ---	1-18
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 242 (C-438), 7 August 1987 (1987-08-07) & JP 62 050466 A (TOAGOSEI CHEM IND CO LTD), 5 March 1987 (1987-03-05) abstract ---	1-18
-/--		



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the International filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the International filing date but later than the priority date claimed

T later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

Z document member of the same patent family

Date of the actual completion of the International search

13 March 2003

Date of mailing of the International search report

03/04/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Teppo, K-M

INTERNATIONAL SEARCH REPORT

Inte Application No
PCT/EP 02/13869

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 014, no. 377 (C-0748), 15 August 1990 (1990-08-15) -& JP 02 138471 A (MATSUSHITA ELECTRIC IND CO LTD), 28 May 1990 (1990-05-28) abstract ---	1-18
A	EP 0 935 284 A (HWANG CHUL JU) 11 August 1999 (1999-08-11) table 3 -----	1-18

INTERNATIONAL SEARCH REPORT

Inter	Application No
PCT/EP 02/13869	

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 08022986	A	23-01-1996	NONE	
US 5976991	A	02-11-1999	CN 1239155 A	22-12-1999
			DE 69901367 D1	06-06-2002
			DE 69901367 T2	29-08-2002
			EP 0964441 A2	15-12-1999
			JP 3055123 B2	26-06-2000
			JP 2000077403 A	14-03-2000
			KR 2000005967 A	25-01-2000
			SG 71928 A1	18-04-2000
JP 62050466	A	05-03-1987	NONE	
JP 02138471	A	28-05-1990	NONE	
EP 0935284	A	11-08-1999	EP 0935284 A1	11-08-1999